California MEDICINE
OFFICIAL JOURNAL OF THE CALIFORNIA MEDICAL ASSOCIATION

Volume 96 FEBRUARY 1962 Number 2

Cardiac Resuscitation Through the Intact Chest

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• **External cardiac compression and external defibrillation were successful in resuscitating 27 consecutive dogs after the production of ventricular fibrillation. Twelve patients survived following circulatory arrest treated with closed chest cardiac compression and, when indicated, defibrillation. Five additional patients were successfully resuscitated but died in the hospital. In fifteen cases, resuscitation was not successful.**

TREATMENT of circulatory arrest resulting from cardiac asystole or ventricular fibrillation must be immediate and definitive. Until recently cardiac resuscitation was effected only by open thoracotomy and manual compression of the heart. Under ideal circumstances in the operating room, with the aid of an anesthesiologist, a trained surgeon can resuscitate most patients. In other locations in the hospital, the need for thoracotomy makes prompt and effective resuscitation more difficult.

Kouwenhoven and his associates[1] described a technique of external cardiac compression which was spectacularly successful in reviving many patients in whom circulatory arrest suddenly occurred. This method, consisting of rhythmic external compression on the lower sternum combined with external defibrillation in patients with ventricular fibrillation, was successful in resuscitating patients on the medical wards as well as in the operating room. It has also been successfully applied to patients in whom cardiac arrest occurred outside the hospital.

Recently, as representatives of the Surgical Committee of the San Francisco Heart Association, we studied this new method. An experimental program was established to confirm the efficacy of the closed chest technique in dogs. Experience was also gained in clinical application.

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Submitted August 9, 1961.

METHOD

Forty mongrel dogs, weighing 10 to 20 kg., were anesthetized with intravenous sodium pentobarbital. An endotracheal tube was inserted and was attached to a positive pressure respirator. The chest was shaved, and two electrodes were applied, one over the cardiac apex and one over the manubrium. The electrocardiogram and blood pressure were continuously recorded. A shock of 110 volts, A.C., of 1 second duration invariably resulted in ventricular fibrillation.

External cardiac compression was then instituted with the Kouwenhoven technique, modified for dogs because of their thoracic contour. The dog was placed halfway between the supine and right lateral decubitus position, and pressure was applied to the left side of the sternum. Rhythmic pressure of about 80 pounds was applied at a rate of 30 to 40 compressions a minute by the heel of the hand, the pressure being maintained half a second each time.

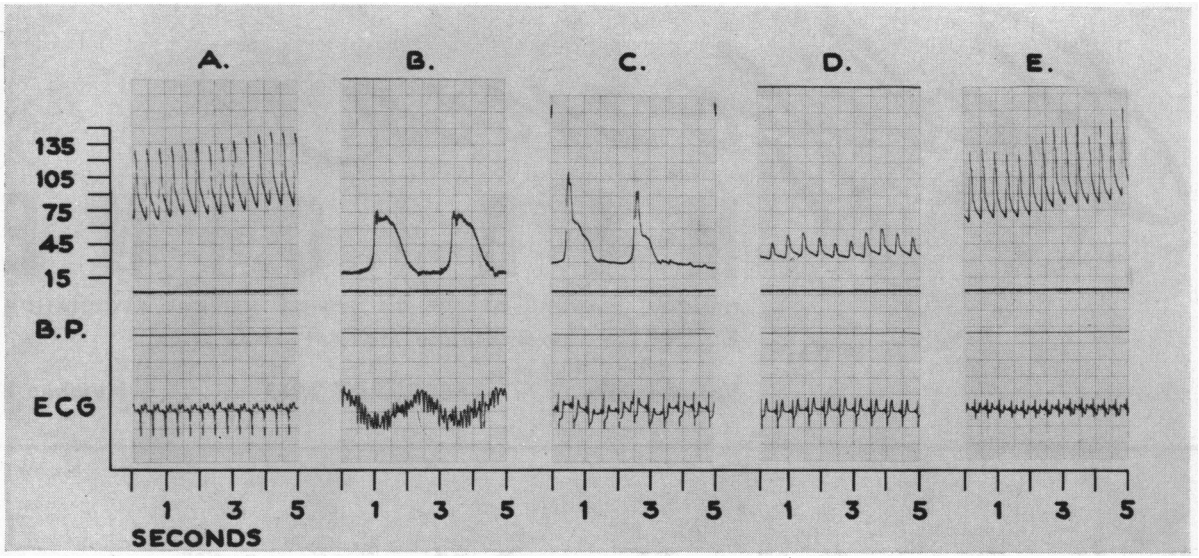


Figure 1.—Arterial blood pressure (in mm. of mercury) and electrocardiogram tracings during experimental ventricular fibrillation followed by defibrillation and recovery in a dog. *A*, control; *B*, during ventricular fibrillation and closed-chest cardiac compression (blood pressure 75/25 mm. of mercury); *C*, after defibrillation with shock of 440 volts (blood pressure supported by cardiac compression); *D*, beginning return of effective cardiac beats, 2 minutes after *C*; *E*, recovery of cardiac function, 1 minute after *D*.

RESULTS

Five of the first 13 dogs died. Defibrillation could not be done in three of these dogs because of inadequate ventilation. It was successfully accomplished in five others but they died later from intraperitoneal hemorrhage secondary to rupture of the liver. The last 27 dogs were long-term survivors after being subjected to ventricular fibrillation for 10 to 30 minutes. In this group the technique of sternal cardiac compression was altered to avoid damaging the dog's high and fragile subcostal liver. Systolic blood pressure of 80 to 125 mm. of mercury was maintained in all the dogs (Figure 1). Defibrillation was obtained in most of the dogs with one, 440-volt, A.C. shock for 0.25 second. In three instances, two such shocks were required. In three experiments one 880-volt shock at 0.25 second was necessary to defibrillate the animal. No dogs had more than first-degree burns from defibrillation. Occasionally ribs were fractured. All the surviving animals were sacrificed after two to three weeks. In no instance did signs of cardiac trauma occur. After defibrillation, the electrocardiogram became normal within several minutes. However, a "normal" electrocardiogram did not necessarily represent effective cardiac function, since some of the animals had severe hypotension. In these cases, cardiac compression was continued until the animal's blood pressure was restored. Intravenous epinephrine (4 cc. of 1:20,000 solution) and sodium lactate (40 cc. 1-molar solution) helped to restore cardiac function. Administration of epinephrine before defibrillation enhanced the defibrillation and caused immediate return of blood pressure to normal or above, following the defibrillating shock.

CLINICAL EXPERIENCE

During a period of six months our clinical experience has encompassed 32 patients with suddenly developing cardiac arrest or ventricular fibrillation. In twelve cases the patient lived and was discharged from the hospital. In this group, circulatory arrest occurred in the operating room, the patient's hospital room, the admission ward, the intensive care unit or in a conference room. External defibrillation was required in four of the patients.

In the remaining 20 patients resuscitative techniques were satisfactory as evidenced by the production of a palpable pulse and the commencement of pupillary constriction. Five were satisfactorily resuscitated from the standpoint of defibrillation and restoration of circulation. Two of these patients died within 72 hours from the effects of cerebral hypoxia. Three died from 3 to 48 hours after resuscitation, due to their intrinsic cardiac disease. Fifteen patients could not be resuscitated. In these there was either severe cardiac disease or a prolonged period between circulatory arrest and the onset of resuscitative measures.

The following case reports are illustrative of our experience.

REPORTS OF CASES

CASE 1. A 73-year-old woman with a fractured hip became pulseless during open reduction under general anesthesia. The electrocardiogram showed

CARDIAC ARREST

ARTIFICIAL CIRCULATION

(Closed Chest Cardiac Compression*) IS EFFECTIVE for Cardiac Standstill or Ventricular Fibrillation

IF SUSPICION of CARDIAC ARREST, DO NOT WAIT for confirmation

PATIENT SUPINE—OPERATOR ABOVE . . . For effective compression mount the bed or adjacent chair.

PLACE HANDS ON STERNUM . . . the HEEL of one hand over the lower sternum, the second hand on the first.

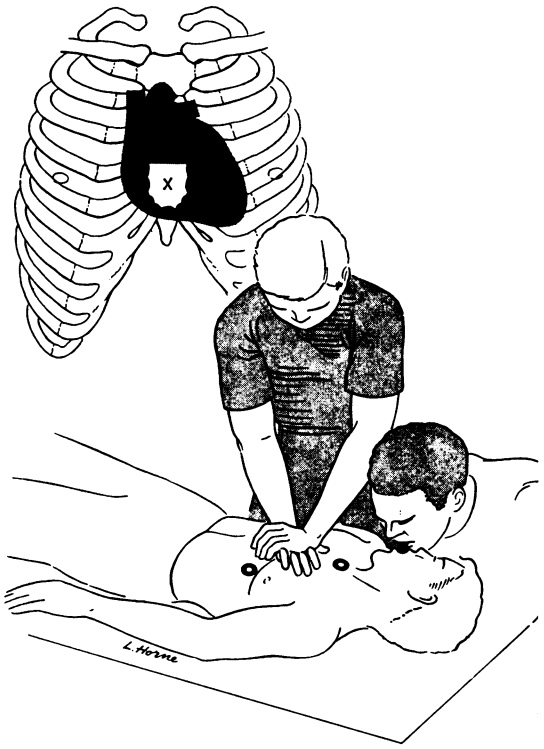
RHYTHMICALLY COMPRESS THE HEART . . . by exerting body weight on lower sternum. MAINTAIN the pressure for 1/2 second and release. Repeat at rate of 30 to 40 a minute. STERNUM SHOULD MOVE 3 to 5 cm. when pressure is applied. DO NOT exert pressure on rib cage or epigastrium.

SIMULTANEOUSLY ESTABLISH VENTILATION . . . Use mouth to mouth or other available means. Call anesthetist.

FEEL FOR PULSE and OBSERVE PUPILS . . . If circulation is maintained, a pulse will be palpable and pupils will constrict. (Pupils dilate with circulatory arrest.)

POSITION PATIENT in Trendelenburg position . . . (head down) to increase cerebral blood flow and guard against aspiration.

DRUGS . . . Give EPINEPHRINE (I.V. or Intracardiac)—4 cc. of 1:20,000 (dilute 1:1000 to 20 cc.) (Repeat PRN.) Combat acidosis with I.V. SODIUM LACTATE (40 cc. of one Molar) or $NaHCO_3$ solution—5 gms. Repeat at frequent intervals. Other drugs as indicated: $CaCl_2$ (10%), norepinephrine, pronestyl, etc.



For VENTRICULAR FIBRILLATION:

VERIFY, if possible, with the ECG. Secure EXTERNAL defibrillator.

APPLY ELECTRODES FIRMLY, one over the cardiac apex, the other over the sternal notch: see diagram. COAT ELECTRODES with conductive jelly.

APPLY SHOCK—440 V.A.C. at 0.25 second. If ineffective, repeat using 3 shocks in rapid succession. If still fibrillating, give epinephrine and alkali. If necessary apply 880 volt shock (0.25 second).

ALWAYS MAINTAIN CARDIAC COMPRESSION until immediately before defibrillation shock. Only an oxygenated myocardium will defibrillate.

MAINTAIN CARDIAC COMPRESSION AFTER DEFIBRILLATION until a good pulse is maintained. The ECG may appear normal while the heart beat is ineffective.

DRUGS . . . Epinephrine, lactate, and other drugs as above.

CONTINUE RESUSCITATION AS LONG AS THE PATIENT RESPONDS
DO NOT STOP PREMATURELY

*The recommended procedures and drugs are the suggestions of the Committee and do not constitute the only acceptable method. Only trained personnel are qualified to use these procedures.

Figure 2.—Posters with the instructions shown on this page, which are dated April 1961, were prepared by the Cardiac Surgery Committee of the San Francisco Heart Association. [Editor's note: Posters are available from your local Heart Association.]

CLOSED CHEST CARDIAC RESUSCITATION

A Joint Statement by the California Heart Association and the California Medical Association

Closed Chest Cardiac Resuscitation or artificial circulation is a first aid emergency procedure which is most useful as a means of assisting the circulation following cardiac arrest or ventricular fibrillation. To be successful, the technique must be combined with properly administered artificial respiration.

The procedure, although simple, requires more knowledge, skill and training than is generally recognized and it is hoped that the technique can be brought to all physicians as quickly and efficiently as possible through a cooperative effort of the California Medical Association and California Heart Association and their local affiliates. The technique should be taught in conjunction with artificial respiration, stressing individual drill and utilizing teaching aids such as manikins and films to insure correct application of both methods.

Instructions to para-medical groups such as dentists, nurses and emergency rescue squads should be carried out only by physicians thoroughly familiar with the technique as well as with the related problems and limitations. Such teaching programs should be part of a continuing study of this form of resuscitation. For the present it is felt that Closed Chest Cardiac Resuscitation is not a technique which could be usefully taught to the average layman.

All hospitals should have access to equipment (such as electrocardiograms and external defibrillators), materials, and trained personnel necessary for the continuing medical care following the successful use of the emergency technique.

January 19, 1962

asystole. Intermittent external cardiac compression for two minutes resulted in return of cardiac activity. Asystole occurred four other times during the procedure and was successfully treated each time with external cardiac compression. Sodium bicarbonate and epinephrine were administered intravenously on several occasions. A sixth period of asystole was treated by thoracic compression two hours later in the recovery room and a seventh episode was treated in the same manner by the night nurse in the Intensive Care Unit 14 hours later. The patient recovered from all of these episodes. Electrocardiograms were consistent with a small myocardial infarct. The patient was discharged from the hospital three weeks later.

CASE 2. A 73-year-old man was admitted to the hospital with a diagnosis of pulmonary edema. Ventricular fibrillation occurred while an electrocardiogram was being taken. Closed-chest compression was instituted and defibrillation was done three minutes later. Ventricular fibrillation recurred and required four additional shocks of 440 volts at 0.25 second.

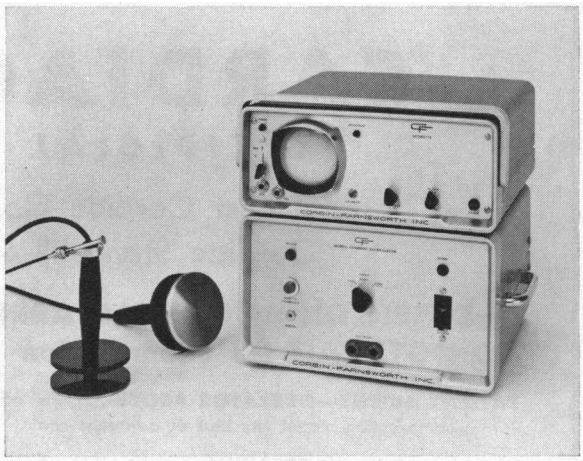


Figure 3.—External defibrillator with electrode switch on electrodes and monitoring oscilloscope. Electrodes to be placed at points shown in Figure 2.

A small first-degree burn occurred at the site of the electrode application. The patient recovered and was discharged from the hospital.

CASE 3. Asystole developed during an operation for retinal detachment in a 65-year-old man. Closed chest cardiac compression resulted in prompt restoration of cardiac action. Spontaneous respiration did not resume for six hours. The patient subsequently had an uneventful recovery and was discharged from the hospital.

CASE 4. Ventricular fibrillation developed suddenly in a 42-year-old hospital employee while he was attending a conference. External cardiac compression and artificial respiration were immediately instituted by nurses at the scene. Fifteen minutes later, external defibrillation was effected. Electrocardiograms were consistent with a small anterior myocardial infarct. The patient had an uneventful recovery and was discharged from the hospital three weeks later.

DISCUSSION

Closed-chest cardiac compression has proven to be effective experimentally and clinically in the treatment of circulatory arrest. On the basis of this experience, we now use external cardiac compression routinely as the treatment of choice for circulatory arrest. The details of this technique are given in Figure 2. Thoracotomy and manual compression of the heart are used only in the operating room.

As with any new technique, errors may occur during closed-chest compression. The most common errors have been:

1. Premature discontinuance of resuscitative attempts.
2. Failure to reestablish ventilation.
3. Improper placement of surgeon's hands on the sternum, causing pressure over the ribs and resultant

rib fractures. In some cases the hands were placed over the liver and caused concomitant lacerations or contusions of the liver.

4. Incorrect position of the surgeon. The surgeon must stay above the patient to be able to exert the weight of his body on the sternum.

The most common errors in defibrillation were:

1. Incorrect placement of electrodes. The electrodes must be well coated with conductive jelly and should be held firmly over the jugular notch and cardiac apex.

2. Excessive time lag between massage and defibrillation. Electric shock should immediately follow the discontinuance of cardiac compression.

3. Incorrectly connected defibrillator (Figure 3). To operate properly, the defibrillator requires a large flow of electricity. It is necessary to plug the unit directly into a wall socket or to use an extension cord as thick as the power cable of the defibrillator.

4. Premature discontinuance of cardiac compression after defibrillation. Electrical and mechanical activity of the heart do not necessarily coincide. Compression should not be stopped until the pulse is palpable.

5. Drugs were not used as indicated. Epinephrine and alkali are useful in most cases to improve cardiac contractility and combat acidosis.

ADDENDUM

Since the preparation of this report, cardiac resuscitation has been successfully achieved in 15 additional patients following application of closed chest cardiac compression and external defibrillation when indicated.

ACKNOWLEDGMENT: The valuable assistance that was given by Edwin Thomsen in this study is gratefully acknowledged.

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REFERENCE

1. Kouwenhoven, W. B., Jude, J. R., and Knickerbocker, G. G.: Closed-chest cardiac massage, J.A.M.A., 173:1064-1067, 1960.